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Original Article

Relationship between the nutritional status of breastfeeding Mayan mothers and their infants in Guatemala

Gianfranco A. Frojo*, Nathaniel G. Rogers*, Manolo Mazariegos†, John Keenan* and Pauline Jolly*

**Department of Epidemiology, School of Public Health, Ryals Building 217, Birmingham, Alabama, USA, and †Institute of Nutrition for Central America and Panama (INCAP), Guatemala City, Guatemala*

Abstract

A case–control study was conducted to determine the association between maternal height and infant length-for-age, and to evaluate how this association is modified by either maternal or infant nutritional status. We hypothesised that maternal excess caloric intake [measured as body mass index (BMI)] would increase the association, while infant nutrition (measured in main meals consumed in addition to breastfeeding) will diminish the effect. Mother and infant pairs in Chimaltenango, Guatemala, were measured for anthropometric values and nutritional status, and mothers were interviewed to elicit nutritional and socio-economic information. Infant length was converted into *z*-scores based on the World Health Organization's (WHO) standards. Odds ratios (ORs), associated 95% confidence intervals (CIs) and the relative excess risk due to interaction (RERI) were calculated. Cases were infants below 2 *z*-scores of the WHO's length-for-age, while controls were infants within the –2 to 2 *z*-score range. Cases ($n = 84$) had an increased odds (OR: 3.00, 95% CI: 1.57–5.74) of being born to a stunted mother (below 145 cm) when compared with controls ($n = 85$). When adjusted for potential confounders, the OR decreased to 2.55 (95% CI: 1.30–5.02). Negative RERI values were produced for the joint exposure of maternal BMI ≥ 25 and maternal stuntedness (RERI: –0.96), as well as for the joint exposure of maternal stuntedness and infant nutrition (RERI: –2.27). Our results confirm that maternal stuntedness is a significant contributor to infant stuntedness; however, this association is modified negligibly by maternal nutritional status and significantly by infant nutritional status, each in a protective manner.

Keywords: stunting, complementary feeding, infant growth, breastfeeding and maternal nutritional status, chronic malnutrition, Guatemala, Mayan populations.

Correspondence: Mr Gianfranco A. Frojo, Department of Epidemiology, School of Public Health, Ryals Building 217, 1665 University Blvd., Birmingham, AL 35294-00222, USA. E-mail: frojo@uab.edu

Introduction

A World Bank study on residents of the Republic of Guatemala classified 51% and 15.2% of the population into poverty and extreme poverty categories, respectively (World Bank 2009). According to a different source, 56.2% of the total population falls within the poverty range (income < US \$1.60 day^{-1}) and 15.7% within the extreme poverty (income < US \$0.70/daily); with higher rates occurring in rural areas (74.5%) compared with the urban areas (27.1%) (PAHO 2007). Also, poverty rates show a stark disparity between indigenous peoples (77.3%) and the non-indigenous population (41.0%) (PAHO 2007).

High levels of poverty are directly related to malnutrition. According to data on nutritional status, 23% of the population in Guatemala is undernourished (consuming less than the minimum dietary

energy requirement) because the average monthly incomes of over 60% of Guatemalan households are too low to cover the cost of the basic food basket (PAHO 2007). More specifically, Guatemala's level of malnutrition was one of the highest in the world in 2002; nearly 23% of children 3–5 months suffered from general malnutrition, while almost one-half suffered from chronic malnutrition in 2006 (World Bank 2009). According to the National Maternal-Infant Survey in Guatemala (Spanish Acronym: ENSMI for Encuesta Nacional Materna Infantil, 2008–2009), 49.8% of the children less than 5 years of age have chronic malnutrition (WHO 2009 standards), the highest rate of Central American countries and one of the top rates around the world (MPHSA 2009). The poorest regions of the country also have the highest rates of malnutrition; 80% of children suffering from chronic malnutrition live below the poverty line (PAHO 2007). Poor women have a higher total fertility rate compared with wealthier women who have an average of two children (PAHO 2007). The incidence of chronic malnutrition among indigenous peoples predominantly in the poor, rural areas (69.5%) is nearly double that of the non-indigenous population (35.7%) (PAHO 2007).

Linear growth is the result of the interaction of both genetic and environmental factors, and maternal height and weight are also important determinants of birth size, particularly in developing countries (Kramer 1987). Recent research from Guatemala has shown that growth during early childhood is an important determinant of height and body measurements throughout life, and that females who are stunted during early childhood are predisposed to be shorter adults (Ramakrishnan *et al*. 1999). The World Health Organization (WHO) categorises adult body mass index (BMI) into different groups: underweight (an indicator of malnutrition; BMI $\leq$ 18.5), normal (18.5 $\geq$ BMI $\leq$ 24.9), overweight (25.0 $\geq$ BMI $\leq$ 29.9) and obese (BMI $\geq$ 30.0) (WHO 1995).

Despite the high percent of chronic malnutrition (stunting) among infants in the country, less than 2% suffer from acute malnutrition (wasting), which features as a relatively 'stable and adaptive status'; in addition, only 1.9% of the female population between 15 and 49 years of age in Guatemala has a BMI below 18.5, and a higher rate of underweight women (3.1%) can be found in central regions of the country such as Chimaltenango (PAHO 2007). As of 2002, the average height of Guatemalan women was 149.2 cm and 25.4% of women fell short of the critical threshold value of 145 cm (PAHO 2007). Moreover, 47.5% of indigenous women measured less than 145 cm, compared with 15.2% of non-indigenous women; on the average, women with secondary and post-secondary education show a 7 cm increase in height in comparison to women with no formal education (PAHO 2007).

Within Guatemala, the traditionally indigenous department of Chimaltenango has been noted for the prevalence of stunting associated with a high risk for chronic malnutrition; the departmental value of chronic malnutrition has exceeded the national reported value of 45.6% in three consecutive censuses from 1986 to 2008 (Delgado 2010).

The socio-economic environment of the Chimaltecos is largely dependent on agricultural production with a large proportion of these crops for export. Approximately 40% of the active workforce finds employment in agriculture, 15.5% in industrial manufacturing and 21.8% in commerce (PAHO 2007). Despite the extensive natural resources and agricultural system, poverty and inequality are among the highest in the region, with higher frequency in rural and indigenous areas. Large disparities are directly related to lack of health care access, education (basic level) and social services (World Bank 2009).

Key messages

- As reported in previous studies, maternal stuntedness is significantly associated with infant stuntedness.
- The effect of maternal stuntedness on infant stuntedness is diminished in infants who consumed meals in addition to breast milk.
- Maternal nutritional status, measured as BMI, did not alter the maternal infant stuntedness association.

We were interested in understanding the high prevalence of stunted infants at approximately 6 months of age in Chimaltenango. Pre- and post-natal growth of infants is associated with adult body composition, but the relative importance of growth during different periods of childhood is still unclear, particularly in stunted populations (WHO 1995). Thus, we conducted this study to investigate the possible relationships between socio-economic and nutritional factors and anthropometric measurements of Mayan mothers and the nutritional status of their infants at 5–7 months of age.

Materials and methods

We conducted a case–control study to investigate (1) the relationship between maternal and infant anthropometrics, especially maternal stuntedness and infant length (adjusted for age); (2) the effects of maternal nutrition (using maternal BMI as surrogate), and the interaction between with consumption of meals by the infant on the maternal stuntedness and infant length. Mothers (16–46 years of age) and their infants (5–7 months of age) from 8 of the 16 municipalities in the department of Chimaltenango were the target population for this study. In an effort to contact as many mothers as possible, seven research workers who previously worked in the municipalities of Chimaltenango (San José Poaquil, Tecpán, Patzicía, Acatenango, San Juan Comalapa, Parramos, Itzapa and Zaragoza) were involved. The research workers had strong connections with the municipality health centres ('Centro de Salud') and the women in the municipalities. They screened the records of women entered in the birth registries at the health centres and identified women eligible for the study based on the inclusion criteria.

Breastfeeding mothers and their singleton, full-term infants 5–7 months of age were included. Women who delivered preterm infants (gestational period < 37 weeks), infants with congenital malformations and multiple births were excluded.

CHWs of each respective municipality visited the mothers at home and told them about the study. Interested women were asked to read the informed consent form and to ask questions or express their concerns and sign an informed consent. The consent form was read to mothers who could not read. All mother–infant pairs who met the inclusion criteria had an equal chance of being recruited into the study. Approximately 54% of mother–infant pairs who were screened were successfully measured, interviewed and entered into the data set (Table 1). Lack of time, interest and spousal disapproval were among the leading reasons for non-participation.

Ethical considerations

No risk was determined to be present for either mother or child participants due to the non-invasive nature of anthropometric measurements and interview procedures. The study protocol was approved by the Board of Ethics of Roosevelt Hospital in Guatemala City, Guatemala, and by the University of Alabama Institutional Review Board. Written informed consent was obtained from each woman before she was admitted into the study.

Data collection

Each mother was interviewed before or after her anthropometric measurements were taken. The questionnaire was constructed to collect information on maternal demographics, socio-economic characteristics, and infant nutrition and health information of the infant and mother. All measurements were taken to the nearest 0.1 (except infant weight, which was measured to 0.01 g). For maternal weight, each mother wore a robe of 10 oz of weight, which was subtracted from the weight given by the scale. Mothers were asked to look straightforward with both arms straight at the sides of her body while she stood on a digital scale (Taylor 7519, Taylor Precision Products, Oak Brook, IL, USA). For maternal height, the mother stood barefoot against a standard stadiometer, which was taped parallel to the wall. The participant placed her heels tightly against the stadiometer with her feet closed, arms to her side, hair loose and down, and chin perpendicular to the floor. A ruler was placed on top of each participant's head and the height was taken. Waist circumference was measured to the nearest 0.1 cm at the narrowest point of the waist using a

Table 1. Maternal and infant demographics adjusted for infant age

Measurement	Controls	Cases	*P*
	n = 85 (above –2 *z*-scores height for age)	*n* = 84 (below –2 *z*-scores height for age)	
Maternal height, mean (SD)	148.36 cm (5.19)	145.50 (5.35)	<0.01
Maternal stuntedness, yes (%)	22 (25.88%)	43 (51.19%)	<0.01
Maternal weight, median (min, max)	53.13 kg (40.02–99.56 kg)	50.83 kg (35.2–87.13 kg)	0.05
Maternal age, mean (SD)	26.94 (5.53)	27.56 (7.50)	0.54
Maternal BMI, median (min, max)	24.38 (18.42–44.95)	23.33 (15.88–43.39)	0.48
Maternal BMI overweight and obese, yes (%)	38 (44.71%)	34 (40.48%)	0.58
Mother literate, yes (%)	78 (55.32%)	63 (75.00%)	<0.01
Dirt or clay floor in home, yes (%)	17 (20.00%)	20 (23.81%)	0.55
Have clean water to drink, yes (%)	6 (7.06%)	21 (25.00%)	<0.01
Refrigerator in home, yes (%)	53 (62.35%)	68 (80.95%)	<0.01
Supplement with formula, yes (%)	17 (20.00%)	16 (19.05%)	0.88
Child eats solid food, yes (%)	56 (65.88%)	49 (58.33%)	0.31
Child consumes ≥1 meal daily, yes (%)	36 (42.35%)	21 (25.0%)	0.02
Child consumes supplements, yes (%)	19 (22.35%)	18 (21.43%)	0.88
Female child, yes (%)	46 (54.12%)	35 (41.67%)	0.11
Child weight, mean (SD)	7.53 kg (0.80)	6.37 kg (0.75)	<0.01
Child BMI, mean (SD)	18.26 (1.50)	17.42 (1.41)	<0.01
Child age at measurement, mean (SD)	6.12 months (0.50)	6.04 months (0.50)	0.31

BMI, body mass index; SD, standard deviation.

flexible measuring tape; with the participant wearing a robe.

Infant weight was measured on a digital scale (SECA Model 334, SECA North America East Medical Sales and Measuring Systema, SECA Corporation, Hanover, MD, USA) either completely nude or with as little clothes as the mothers permitted. Subsequently, the clothes that the infant wore during measurement, if any, were weighed separately and subtracted from the original weight measurement. Infant length was measured while the infant was laying down in the infantometer (SECA Model 416) against the firm and flat surface of the measuring board with a plastic rod to push against the feet. Socks and shoes were removed before measurement.

A trained female anthropometrician conducted maternal measurements in a private area. The investigators performed interviews and infant measurements with the assistance of the CHWs. Two measurements were taken, and if there was any inconsistency between the measurements (±0.01 kg weight; ±0.1 cm height), a third measurement was taken and the average of the three measurements was recorded.

Statistical analysis

Cases were defined as children who were two *z*-scores below the WHO's length-for-age growth standard. *z*-Scores were calculated with the *igrowup_restricted* SAS macro downloaded from the WHO (WHO 2011). Controls were children between –2 and 2 *z*-scores for WHO length-for-age. No child in the cohort exhibited a length-for-age *z*-score above 2. BMI values were calculated in accordance with WHO international standards from height and weight measurements taken during the visit. Mothers with BMI scores ≥25 (overweight and obese) were grouped together for calculation of relative excess risk due to interaction (RERI). Stunted mothers were classified as those below 145 cm in height.

Cases were compared to controls with respect to demographic factors by *t*-test, Wilcoxon Mann–Whitney test or chi-square for normally distributed continuous variables, non-normally distributed continuous variables and categorical variables, respectively. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to measure the association between maternal stuntedness and infants 2

z-scores below the WHO's standard growth curve. Univariate and multivariate analyses were conducted to calculate unadjusted OR and OR adjusted for potential confounders. We wanted to investigate how maternal stuntedness and maternal or infant nutrition interacted to affect infant length. RERI values were calculated for the joint exposure of maternal stuntedness and maternal BMI ≥ 25 and maternal stuntedness and infant nutrition. RERI measures the additional risk experienced as a result of joint exposures (Rothman & Greenland 1998). The recommended reporting of interactions is to report each effect separately and then the combined effects compared with the unexposed group. This method allows the use of the unexposed group as a reference group to evaluate interaction on both an additive and multiplicative scale (de Mutsert *et al*. 2009). As we were primarily interested in how the main effect of nutrition modifies any effect of maternal stuntedness, and as RERI values adjusted for covariates vary across strata and are difficult to interpret, RERI values are not adjusted for potential confounders (Skrondal 2003). Analyses were conducted with SAS 9.2 (SAS Institute Inc., Carry, NC, USA); *P*-values ≤ 0.05 (two-sided) were considered statistically significant.

Results

One hundred and sixty-nine mothers and their infants were recruited into the study. Eighty-one of the infants were girls and 88 were boys. Maternal and infant demographic characteristics are listed in (Table 1). The average child age at measurement was approximately 6 months and did not differ between groups. Mothers of cases were of shorter stature and higher weight, more frequently literate, more likely to report access to clean water and refrigeration for foods in the home than mothers of controls. The average maternal height of the study population was 1.47 m. Approximately 38.5% of the mothers exhibited stunted height (height < 1.45 m). A majority of mothers (62.7%) had a hip circumference above the cut-off point for central adiposity that increases risk for metabolic diseases. A large percent of the mothers (70.41%) displayed a waist-hip ratio (WHR) of 0.84 or above, which may be a risk factor for cardiovascular disease (Welborn *et al*. 2003). Forty-two per cent of mothers are classified as overweight or obese according to the WHO BMI classification system; almost 16% fell in the range of obese (BMI ≥ 30), 26.3% were overweight (BMI ≥ 25), 55.04% were of normal nutritional status (18.5 ≤ BMI ≤ 24.99) and only 2.49% were classified in the underweight (BMI < 18.5) range. There was a stronger correlation between maternal waist circumference ($r = 0.77$, $P = 0.007$) and infant height than maternal height and infant height ($r = 0.34$, $P < 0.001$). Further research will be necessary to establish if maternal waist circumference is a good predictor of infant height.

Nutritional status of the infants was determined using the WHO's *z*-scores. The average height-for-age *z*-score (HAZ) of the infant was –2.01, indicating the prevalence of stuntedness in the cohort. Among males, the average *z*-score value dropped below the study group mean to –2.07. Female infants had an average *z*-score value higher than the group mean at –1.92. The mean weight-for-age *z*-score (WAZ) fell within the normal range ($-2 < z < 2$) expected for infants of normal nutritional status ($z = -0.86$). The mean weight for height also fell within the normal nutritional status range ($z = 0.69$). Similarly, the BMI for age *z*-score was in the normal value range (0.43).

The crude odds of having a child below 2 *z*-scores on the length-for-age WHO growth curve were three times greater (OR: 3.00, 95% CI: 1.57–5.74) for mothers below 145 cm in height than mothers with height above 145 cm. We ran a series of models; the first an unadjusted model, the second adjusted for maternal variables significant in univariate analysis and 'child consumes ≥1 meal daily' (OR: 2.25, 95% CI: 1.12–4.51). Our final model included only variables significant in multivariable analysis. After adjusting for potential confounders including having clean water and maternal literacy in the final model, the OR diminished to 2.55 (95% CI: 1.30–5.02) but remained significant. The analyses exploring interaction are displayed in Table 2. Mothers who were stunted and had a BMI < 25 had significantly higher odds of having an infant 2 *z*-scores below the WHO length-for-age standards (3.42, 95% CI: 1.43–8.09).

Table 2. Relative excess risk due to interaction for the effect maternal obesity vs. consuming one or more meals of stunted mothers has on the chances of having a stunted child determined from an unadjusted, saturated model

		Stunted mother		RERI
		No	Yes	
Maternal BMI ≥25	No	1	3.42 (1.45–8.09)*	–0.97
	Yes	0.98 (0.44–2.16)*	2.43 (0.54–11.03)*	
Infant consumes 1 or more main meals daily	No	1	3.56 (1.60–7.90)*	–2.27
	Yes	0.72 (0.32–1.62)*	1.01 (0.24–4.09)*	

BMI, body mass index; RERI, relative excess risk due to interaction. *Odds ratios presented are not adjusted for potential confounders as detailed in the Methods section.

Maternal BMI ≥ 25 modified the effect but only slightly, resulting in a RERI of –0.97; therefore, the RERI value indicates that the two exposures, stuntedness and obesity, do not interact with each other to help increase the odds of having a stunted child. Stunted mothers who did not feed their children one or more main meals similarly had an increased odds of having a stunted child (3.56, 95% CI: 1.60–7.90); however, feeding a child main meals dramatically modified the effect, yielding a RERI of –2.27.

Discussion

The low percentage (2.37%) of underweight mothers based on BMI coincides with the Guatemalan and Chimalteco averages 1.9% and 3.1%, respectively (PAHO 2007). A high proportion (42.61%) of the mothers in the study is either overweight (26.63%) or obese (16.00%), which directly reflects the rising rates of overweight and obesity in Guatemalan families (Asfaw 2011). These increasing rates in adult weight and obesity, coupled with longitudinal growth failure in childhood, predispose this population to high risk of developing future health risks, specifically hypertension, high blood glucose levels and high serum lipid content (Stein *et al*. 2005). In addition to these risk factors, 70.4% of women in our study had a WHR above 0.84, indicating an even higher risk for developing certain metabolic and cardiovascular diseases (Welborn *et al*. 2003).

The average height of the mothers (1.47 m) was below the Guatemalan average of 1.49 m (PAHO 2007). Approximately 38.5% of mothers in our study fell beneath the threshold-stunted height of 1.45 m, far below the reported average noted by Delgado in 2010 for Chimaltenango (82.1%) and also lower than the 47.5% stunting for indigenous mothers of Guatemala (PAHO 2007).

Approximately 50% of the infants were stunted (<–2 *z*-score HAZ). The growth characteristics of the study population are consistent with the recent reports in the same region (Mazariegos *et al*. 2010; Krebs *et al*. 2011a,b). Evidence suggests that female infants who exhibit stunting in childhood will not outgrow their stuntedness (Ramakrishnan *et al*. 1999). Similar to their mothers, short stature in infants continues to develop as a primary concern over weight gain; faster rate of infant weight gain compared with longitudinal growth predisposes infants to a higher risk of developing high BMI as adults, similar to what is reflected in the maternal population (Ramakrishnan *et al*. 1999).

Our results support the association of maternal stature and offspring stuntedness. A 1 cm increase in maternal height is associated with decreased risk for offspring stunting and underweight (Ozaltin *et al*. 2010). When maternal height was compared with other variables, the results showed that maternal height has an effect 1.5 and 2 times greater than poverty level and education, respectively (Ozaltin *et al*. 2010). A similar study found that for every 1 cm increase in maternal length and 100 g increase in maternal weight, the mother's newborn infant's birth length and weight increased by 0.2 cm and 29 g, respectively (Ramakrishnan *et al*. 1999).

Referring to non-anthropometric variables, infant cases were less likely to consume one or more meals daily, defined as any complementary feeding or supplementation to breastfeeding. Our findings

indicate that the odds of infant stuntedness increased by 3.56 (95% CI: 1.60–7.90) when a stunted mother elects to not feed her infant one or more main meals as solid food or supplements daily. The analysis indicates that consumption of solid food or supplements by infants in our study population may lead to an increase in infant longitudinal growth. This finding is in accordance with a previous study that demonstrated the direct benefits of increased infant calorie supplementation on infant longitudinal growth after 3 months of age (Delgado *et al*. 1982). The investigation into the impact of solid or supplemental caloric intake prior to 6 months of age may require further analysis before challenging Guatemalan or WHO feeding guidelines of electing to solely breastfeed for the first 6 months after birth.

Results of this study should be interpreted in light of several limitations. Not all potential participant pairs were contacted due to time constraints; each health municipality worker had limited time to find all potential research participants, explain the research project, read and obtain signature on the informed consent and find a central location for measurement. Given that not all eligible and potential participants were included in the study, the sample population was reduced and potentially biased. However, it is important to note that the characteristics of the sample study population are consistent with recent reports, which confirms that this study group is representative of the population studied. The use of BMI as a surrogate nutritional indicator for nutritional status may not be initially seen as the most ideal marker due to accumulation of prior dietary history before involvement in the study. However, as noted by Shetty & James, BMI is considered to be a suitable and objective anthropometric indicator of nutritional status of an adult (Shetty & James 1994). Other preliminary data suggest a protective effect of maternal obesity on infant length-for-age; however, maternal obesity does not significantly affect the odds of producing a stunted child, but a slight risk is noticeable. Maternal height was the best predictor of infant height both in non-obese and in obese women.

Although this study did not estimate the micronutrient contribution of the complementary solid foods given to the infants, it is very likely that supplemental solid food intake would contribute both calories and micronutrients. As reported in the literature in response to the protein vs. energy paradigm, much of the effect on growth was thought to be attributed to the energy supply (Delgado *et al*. 1982). In the current study, most infants were proportionate with hardly any wasting, making the presence of energy deficiency unlikely; therefore, high rates of stunting cannot be explained by energy deficiency. On the other hand, it is now recognised that key micronutrients such as iron and zinc (for which breast milk is a limited? source beyond 4- to 6-month post-partum) play an important role in infant growth. The early introduction of solid foods after 6 months of age or supplementation with micronutrients becomes critical in terms of optimal growth and development. A more recent multicountry study, including a sample of Guatemalan infants, indicated that meat consumption was associated with reduced stunting. This is in accordance with the important role of key micronutrients and provides support for the findings of this study (Krebs *et al*. 2011a,b).

Conclusion

Our results confirm that, as expected, maternal stuntedness is a significant contributor to infant stuntedness or below average height. Our data suggest that supplementation or solid food consumption before 6 months of age may have an impact on infant longitudinal growth and overall nutritional status.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

MM conceived the idea and worked with PJ in developing the protocol for the proposal. MM and PJ supervised GAF and NGR in collecting the data and in writing the original draft of the manuscript. JK analysed the data, prepared tables and wrote the initial draft of the result. All co-authors worked together to interpret the results and to critically review and revise all sections of the text for important intellectual content.

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